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COMPARISON OF ABLATION RESISTANCE AND THERMAL CONDUCTIVITY OF C-PH AND CNT COMPOSITE LAMINATES

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ABSTRACT

Supersonic aerospace vehicles which operate at very high speeds are supposed to sustain lots of heat due to skin friction. There is always a need for materials which are light in weight and show excellent thermal resistance. The current study compares the thermal conductivity and the ablation resistance of CNT and C-Ph laminates through series of experimental procedures.

KEYWORDS: Ablation Resistance, Thermal Conductivity of Composites & C-Ph and CNT

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Original Article

INTRODUCTION

The mechanical and material properties with less weight of structures make composite materials one of the main ingredients of aerospace vehicle structures. Vehicles which travel at very high speed and harsh operating conditions undergo lots of thermal resistance. Ablation resistance and thermal conductivity are very important thermal properties a material, operating in these harsh conditions requires.

S.Subha and team investigated the thermal and ablation characteristics of carbon/phenolic composites loaded with zirconia (Zr) coated graphene Nanoplatelets. The ablation was investigated under oxyacetylene welding test at a heat flux of 2100 kW m−3. [1]

D.Cho in his research concluded that micro structurally coated composite exhibit increased ablation performance than the uncoated one. [2] He and his team also researched on Ablation properties, the microstructural comportment of ablation and thermal stability different carbon-Fiber-reinforced composites made up of four different matrices, a phenolic matrix, a carbonaceous matrix, a carbonaceous matrix containing impregnated resin and a carbonaceous matrix containing pyro carbon.

The ablation properties of the composites used were quantitatively evaluated by performing ablation tests with a plasma torch. The ablation properties of both the carbon Fibers and the composite matrix have been compared through an electron-microscopy testing method.[3]

Shen Xuetao and team performed an experiment on the phase composition and morphology of the composites by X-ray diffraction and scanning electron microscopy. They also tested the ablation properties using an oxyacetylene torch concluding that the linear and mass ablation rates of the composites after doping with ZrC

reduced by 83.0% and 77.0%. [4].

R. C. Progelhof and team experimented with different methods of determining the thermal conductivity of composite material and came out with a conclusion that Lewis and Nielsen's equation fitted best with the experimental results. [5]

G. Sravanthi and team had conducted an investigation on ablative properties of C-Ph and C-Ph coated with zirconia. [7]

EXPERIMENTAL INVESTIGATIONS TO DETERMINE THERMAL CONDUCTIVITY AND ABLATION PROPERTIES OF THE COMPOSITES

Hot Guard Testing Method

The above-mentioned technique is one of the best ways to test the axial thermal conductivity of materials. The principle of the measurement lies with passing the heat flux through a known sample and an unknown sample and comparing the respective thermal gradients, which will be inversely proportional to their thermal conductivities. Most commonly, the unknown is sandwiched between two known samples for the account for minor heat losses that are very difficult to eliminate.The figure below shows the schematic diagram of hot guard testing method.

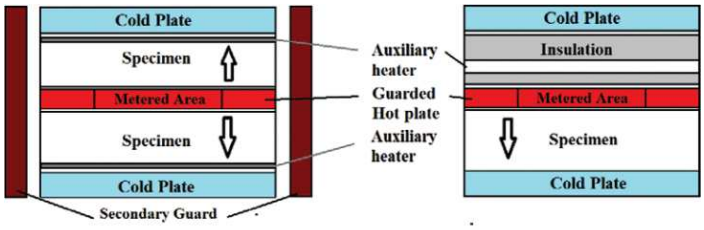

Figure 1: Hot Guard Testing Method [6]

Determination of Ablation Resistance by Plasma Arc Jet Testing Method

Plasma jet testing was conducted to determine the ablative properties. The composite materials of diameter 10 mm * 17.6 mm were manufactured. Samples are circularly covered with the guard rings whose material is same as the test specimens. Guard ring ensures a single directional heat contact of the test specimen to the plasma arc jet.

Figure 2: Plasma Arc Jet Testing Method

Plasma arc with a speed equal to 356 m/s have been fired on the specimens at 4.0 MW/m² for a time of 30 seconds. To measure the back face temperature of the specimen during the test duration. K-Type thermocouples were used to measure the back temperature. Ablation rate is found out by concentrating on weight loss on the specimen with respect

to time. The continuous repetition of the experiment will give the average value of ablation rate of the specimens.

RESULTS AND DISCUSSIONS

Results of Hot Guard Testing

C-Ph Composite Laminate

The below mentioned experimental parameters were considered

- **Reference material:** fused silica
- **Reference diameter:** 25mm
- **Reference thermal conductivity:** 1.00W/Mk
- **Sample diameter:** 25mm

Table 1: Hot Guard Test Results for C-Ph Composites

S. No	Time	Sample Top Temp (Deg C)	Sample Bottom Temp (Deg C)	Average Temp (Deg C)	Thermal Conductivity (W/Mk)
1	65	42.4	30.50	36.10	0.488
2	145	56.7	32.10	47.94	0.503
3	225	113	72.50	91.73	0.515
4	305	173.78	112.10	142.78	0.526
5	345	175.45	112.40	143.79	0.521
6	390	175.67	112.30	143.89	0.517

CNT Composite Laminate

The below mentioned experimental parameters were considered

- **Reference material:** fused silica
- **Reference diameter:** 25mm
- **Reference thermal conductivity:** 1.00W/Mk
- **Sample diameter:** 25mm

Table 2: Hot Guard Test Results for CNT Composites

S. No	Time	Sample above Temp (Deg C)	Sample Below Temp(Deg C)	Average Temp(Deg C)	Thermal Conductivity (W/Mk)
1	65	30.0	23.6	26.8	0.694
2	145	48.6	35.9	42.1	0.685
3	225	96.6	66.9	81.8	0.682
4	305	153.6	105.8	129.7	0.683
5	345	155.2	106.6	130.9	0.680
6	390	154.9	106.2	130.6	0.678

Results of Plasma Arc Jet Method

Table 3: Results of Plasma Arc Jet Testing

S. No	Specimen I.D	Density g/cc	Heat Flux (W/mm^2)	Test Duration (s)	Erosion Rate (mm/s)	Back Wall Temperature at the end of Test Duration (°C)
1	Blank (C-Ph)	1.24	4	30	0.052	168
2	CNT	1.4	4	30	0.015	120

CONCLUSIONS

- Hot guard test and plasma arc testing were conducted in C-Ph and CNT laminates to compare thermal conductivity and ablation resistance (Table 3) respectively.
- It was observed that C-Ph composite had more erosion rate than CNT composite.
- Comparison of thermal conductivity of C-Ph and CNT is shown in the plot below

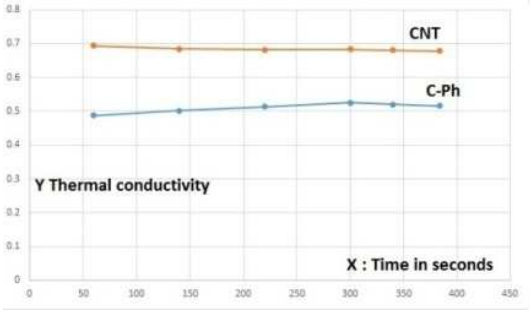

Figure 3: Comparison of the Thermal Conductivity of C-Ph and CNT Laminates

REFERENCES

1. *S Subha, Dalbir Singh, and P S Venkatanarayanan," Thermal, ablation and mechanical properties of carbon–phenolic composites reinforced with zirconia coated graphene nanoplatelets", Published 12 January 2018, IOP Publishing Ltd, Materials Research Express, Volume 5, Number 1.*
2. *Donghwan Cho, "A microstructural study of the improved ablation resistance of carbon/phenolic composites fabricated using H3PO4-coated carbon fibers", Journal of Materials Science Letters, January 1996, Volume 15, Issue 20, pp 1786–1788.*
3. *Donghwan Cho, Byung .I.Yoon,"Microstructural interpretation of the effect of various matrices on the ablation properties of carbon-Fiber-reinforced composites", Composites Science and Technology, 61 (2001) 271-280.*
4. *Shen Xuetao, Li Kezhi, Li Hejun, Du Hongying, Cao Weifeng, Lan Fengtao, "Microstructure and ablation properties of zirconium carbide doped carbon/carbon composites", Carbon, 4 8 (2 0 1 0) 3 4 4 – 3 5 1, doi:10.1016/j.carbon.2009.09.035.*
5. *Raja, R., and Sabitha Jannet. "Experimental Investigation of High Speed Drilling of Glass Fiber Reinforced Plastic (GFRP) Composite Laminates made up of different Polymer Matrices."*
6. *R. C. Progelhof J. L. Throne R. R. Ruetsch, "Methods for predicting the thermal conductivity of composite systems: A review", Polymer Engineering and Science, September 1976, Vol. 76, No. 9.*

7. *Numan Yüksel, "The Review of Some Commonly Used Methods and Techniques to Measure the Thermal Conductivity of Insulation Materials", Materials Science "Insulation Materials in Context of Sustainability", DOI: 10.5772/64157.*

8. *Sravanthi.G, C.Satya Sandeep, Swathi.G, Leena.Ch, Ratan.A " Hot guard and plasma jet evaluation of C-Ph and C-Ph fused with Zirconium composites," International Journal of Mechanical Engineering and Technology (IJMET), Volume 8, Issue 7, July 2017, pp. 1034–1051, Article ID: IJMET_08_07_112. ISSN Print: 0976-6340 and ISSN Online: 0976-6359.*

9. *G. Sravanthi, Hanuma.P, C.Satya Sandeep, "Residual stress measurement of Aluminum 5052 using X-Ray diffraction method", International Journal of engineering research and management, ISSN: 2349-2058, Vol 3, Issue 12, December 2016.*